12. *On the* ORIGIN *of the* DUNMAIL RAISE (LAKE DISTRICT). By RICHARD DIXON OLDHAM, Esq., F.G.S. (Read February 6th, 1901.)

EVERY visitor to the English Lakes, who has travelled by coach from Windermere to Keswick, must know the Dunmail Raise, that deep-cut wind-gap through the mountains which forms, if properly understood, one of the most remarkable natural features that it has been my lot to see, one of the most difficult of satisfactory explanation, and one which has not by any means attracted the attention that it deserves.

Cut down to a height of 782 feet above sea-level, the gap lies between the masses of Helvellyn (3118 feet) on the one hand, and High Raise (1500 feet) and the Sca Fell Pikes (3210 feet) on the other; it forms a typical instance of the lückenpass of Richthofen,[1] or wind-gap of the Americans, but differs from the majority of such in one important point which will be brought out in the sequel.

Approaching the pass from the north, there is seen a deep-cut valley, broad and open at the bottom, from which the sides rise steeply in, what Mr. Marr has named, the curve of erosion; it is, in fact, a typical stream-valley, and a valley properly belonging to a volume of water to which the term river is applicable; yet when this gradual ascent is traversed the road, after a short steep rise over a moraine, crosses an insignificant little streamlet, the Birkside Gill, which is utterly out of proportion to the valley down which it now flows, and is a very glaring instance of what Prof. W. M. Davis has called a misfit. As the road goes on, it traverses the same valley-shaped gap, which ordinarily contains no stream at all, till, at the summit, the Raise Beck is seen coming down from the east. Here is a case of divided drainage, for while the bulk of the water flows away to the south, a small portion, when the beck is in flood, finds its way to the valley which has just been traversed.

So far nothing extraordinary has been seen, the features are such as may be observed in any wind-gap due to the beheading of the stream which once filled it, but as soon as the descent is commenced a great contrast is noticed. Instead of a steep descent on the further side of the crest, the slope of the valley is at first almost imperceptible. Then come some large moraines, signs of erosion are seen in the stream-bed, there is a steep bit of descent in the road, but the valley maintains the same type as on the other side of the divide, and the Raise Beck is as glaring a case of misfit to the valley that it occupies as the Birkside Gill.

The commonest mode of origin of a wind-gap is when a stream draining a considerable area, and consequently of considerable volume, has cut a deep valley and is then beheaded by another stream which, favoured by a steeper gradient, or cutting back along a band of soft rock, penetrates the drainage-area of the first and directs its headwaters to a new course. In this case, after a gradual ascent along an open valley, there is an abrupt descent from the summit-level to a deep-cut valley. Such is not the case in the Dunmail Raise.

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[1] 'Führer für Forschungsreisende' 1886, p. 703.

Another form of wind-gap will not show an abrupt descent into a larger valley at the head of the gap, but will descend from the summit-level through (what Prof. W. M. Davis has called) an obsequent valley to a main valley crossing the head of the gap: an obsequent valley being one which has been cut back along the beheaded valley, on account of the lesser resistance offered by it, as compared with the higher ground on either side. In this case there will be an open valley on the one side of the summit-level occupied by no stream at all, or by a stream which is too small for it; on the other side the obsequent valley, having been formed by the stream which occupies it, will fit the stream that it carries and will be narrower and steeper-sided than the beheaded valley beyond the summit-level. This again is not the case with the Dunmail Raise.

A third mode in which a gap may be formed by erosion is where two streams opposite each other cut back into the same mass of high ground. Here the two valleys cutting back against each other will cause a notch to be cut in the ridge where they meet, but in such a case the summit of this notch will be narrow, if not sharp, and the slopes on either side steep. In an old land-surface which has long been exposed to denudation, and where all the surface-forms are rounded off by weathering, a notch with a cross-section not unlike the Dunmail Raise might originate in this way; but then the profile of the watershed would have a very different form, and in a hilly country of steep slopes and craggy summits the notch would have a shape much more like Striding Edge than the Dunmail Raise. Moreover, the streams draining from both sides of the watershed would fit their valleys, which is not the case in the Dunmail Raise.

In short, wherever a wind-gap is formed by the recession of watersheds, consequent on stream-action, the streams on one or both sides of the watershed must fit their valleys; and it is impossible in this way to form a gap in which the valleys on both sides of the summit-level are too large for the streams which now flow in them.

Another mode of origin which might be, though I am not aware that it has been, suggested, is that the gap was carved out by an ice-sheet. Against this hypothesis may be placed, first of all, the absence of any evidence of an ice-sheet having ever swept across these mountains; and secondly, a glacial origin seems precluded by the fact that at both ends the gap is crossed by the lateral moraines of the glaciers which issued from the Wythburn Valley on the one hand and the Greenburn Valley on the other, while the central portion is dotted with heaps of avalanche-moraine,—that is to say, débris which rolled down the snow-slopes and was left on the ground when the snow melted away. The Birkside Gill shows old stream-gravels, washed down from the hills above, overlain by this avalanche-moraine material, indicating that the gap was in existence before the Glacial Period. The sides of the gap, too, where rock is exposed, show no signs of the ice-scouring which should have been most conspicuous if the gap had been cut out by ice; this is especially well seen at the southern end of the gap, where the spur between the Greenburn Valley and that of the Dunmail Raise has been smoothed and rounded up to a certain point by the glacier which overflowed from the former, and the boundary between the glaciated and unglaciated hillsides can be traced running down in a slant to the great moraines which lie at the southern entrance of the gap.

All this shows that the formation of the gap of the Dunmail Raise cannot have been due to ice, for the reason that it was in existence, in very much its present form, before the Ice Age commenced.

There remains, so far as I can see, but one other possible explanation, namely, that the gap was formed by a river which once flowed across the whole breadth of the Cumberland hills, whose volume and power were sufficient to enable it for a long time to cut down its channel as the hills were elevated, till, finally, whether from an increase in the rate of elevation, or a decrease in the volume and power of the river, or both combined, it was no longer able to do so, the river-valley was split into two portions, and the direction of flow of the upper waters reversed. In this way, and this way only, does it seem possible to explain the peculiar features of the gap which forms the Dunmail Raise.

This being so, it is of interest to determine whether the river flowed from north to south, or in the reverse direction, and here there is little room for doubt. In the first place we have the unequal slopes on either side of the summit-level: when a river-valley is crossed by a symmetrical axis of elevation, which splits it into two portions by the formation of a barrier across it and the reversal of flow of the upper waters, the slope will be steeper on what was the down-stream side than on what was originally the up-stream side of the crest; for, in the first case, the slope due to deformation is increased, and in the second diminished, by the original slope of the valley. Now, I find that the Ordnance Survey gives the height above sea-level at the summit of the pass as 782 feet; at Wythburn, 9 furlongs to the north, measured in a straight line, the level is 568 feet, giving a mean slope of 189 feet per mile; 7½ furlongs to the south of the summit the height of the road is 550 feet, or a mean slope of 247 feet per mile. If, instead of the heights on the road, those of the valley-bottoms are taken, these slopes would be slightly increased, and in a larger degree on the south than on the north, so that the evidence of the surface-slopes points to the river having flowed from north to south.

A similar indication is given by the surface-features. As one travels southward from the Dunmail Raise the road descends into the broad and open valley of Grasmere; below Grasmere the valley contracts somewhat, but is still that of a larger stream than the one which formed the Dunmail Raise, and, a little farther on, the open valley of the Windermere Lake is entered. Travelling in the reverse way, we descend from the pass into the Thirlmere Valley, much narrower and steeper-sided than the valley on the other side of the pass, and at the lower end of the lake this valley divides into that of the Noddle Beck, through which the coach-road to Keswick runs, and the St. John's Vale, through which the waters of Thirlmere find their present outlet. Both of these valleys are smaller than the Thirlmere Valley, and St. John's Vale in particular has much more the aspect of belonging to the headwaters of a stream large enough to have carved out the gap of the Dunmail Raise, than of the lower part of its valley. It looks as if the two valleys represent two tributaries, which united at what is now the lower end of Thirlmere, to form a river, flowing southward to what are now Grasmere and Windermere.

It is noteworthy that the valley of the Noddle Beck is faced by the depression between Saddleback and Skiddaw, now drained by the Glenderaterra and Caldew, which may not improbably mark the course of the upper waters of the Dunmail River. It will probably be impossible to establish this definitely, and it must remain a suggestion; but it is not improbable that the diversion of the upper waters of the Dunmail River into the Derwent, and their removal to the west, may have caused such a decrease of power as to make the old river no longer capable of coping with the barrier, which was rising across its course lower down, and so caused the division of its drainage-basin and the ultimate reversal of the direction of flow of its upper portion.

Against the original southerly flow of this river can only be set the valley of the Wythburn, which joins the Thirlmere Valley, leaving an acute angle between it and the Dunmail Valley. An examination of the map shows, however, that the upper waters of this stream flow in a valley running at right angles to the course of the old Dunmail River, while the lower portion alone bends slightly northward, and the level at which this bend takes place is below that of the crest of the Dunmail Raise. It is, consequently, possible that the northerly bend of the lower portion of the Wythburn Valley is of a later date than the separation of the old Dunmail Valley into two portions, and due to the altered conditions of erosion set up by that separation. In any case, the obliquity of this valley would not preclude the possibility of a southerly flow of the river to which it was tributary, and against it must be set the bifurcation of the valley at what is now the lower end of Thirlmere, and the fact that on the south side of the watershed all the larger tributaries join the main valley in what would be the normal direction for a southward-flowing river.

There remains the consideration of how the explanation of the origin of the Dunmail Raise offered above affects, or is affected by, the accepted ideas regarding the elevation of the mountain-mass which it traverses. Since the time of Hopkins's paper,[1] it has been recognized that the elevation to which these mountains owe their present existence is of much later date than the principal disturbance of the rocks composing them. In the paper just quoted, the axis of elevation is regarded as a linear one, the elevation attaining its maximum to the westward, in the neighbourhood of the Sca Fell Pikes, and lessening to the eastward. In more recent years the concept of a radially arranged drainage, originally due to the poet Wordsworth, has been taken into scientific literature; and in a geographical paper published by Dr. H. R. Mill in 1895,[2] the symmetry of the mountains is regarded as radial, not linear. He considers the mountains as carved out of a dome, traversed from north to south by two long depressions:—that of Thirlmere, Dunmail Raise, and Windermere, and that of Borrowdale, Stake Pass, and Conistone; and he illustrates his paper by a skeleton-map of the district, on which a series of circles are drawn round a centre on High Raise, midway between the Dunmail Raise and Stake Pass. On this map the lakes and principal valleys are shown to converge towards this assumed centre of elevation. In 1889[3] Mr. J. E. Marr had propounded the same view, and published a skeleton-map, very similar to that of Dr. Mill but without the concentric circles, and with geological indications showing that the present centre of maximum elevation is widely different from the axis of disturbance of the Palæozoic rocks. He considers that the only agency which could produce a dome-shaped uplift of the form postulated was the intrusion of a laccolite.

In the maps referred to, only the present lakes and river-courses are shown, and in them an appearance of radial symmetry can be easily detected, which disappears if the old Dunmail River is restored,[4] and also if a relief map of the district is examined. On a map of this character, it is seen that the mountain-mass is divided into three portions, that of Skiddaw on the north—which lies outside the present discussion—of the Helvellyn-Shap Fell ridge, and of the Sca Fell-High Raise ridge; the latter being partially interrupted by the Stake Pass, as is the Helvellyn-Shap Fell ridge by the Kirkstone Pass. In each of these two masses, considered separately, the drainage can be better regarded as diverging from an axis than from a point. In the western mass, the drainage is more radial: we have it in Borrowdale flowing northward; in Buttermere flowing north-westward; Ennerdale towards the west; Wastwater to the south-west; while a ridge runs southward to the Old Man of Coniston, and breaks the drainage into smaller valleys flowing south-westward and south-eastward. On the opposite side of the Dunmail Raise the drainage is palpably axial: there are the two large valleys of Ullswater and Haweswater flowing north-north-eastward, and a number of smaller valleys drain the southern slopes of this ridge.

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[1] Quart. Journ. Geol. Soc. vol. iv (1848) p. 70.

[2] Geogr. Journ. vol. vi (1895) p. 46.

[3] Geol. Mag. 1889, pp. 150-55; see also Geogr. Journ. vol. vii (1896) p. 602.

[4] It is doubtful whether the Dunmail Raise is the only trace left of an older, now vanished, drainage. The Kirkstone Pass has much the appearance of a valley beheaded by the Stock Gill cutting back from the south, but the resemblance is not complete. The ascent of the valley, which drains northward, is not continuous to the summit, towards which it flattens off, and there is a slight descent, before the rapid drop into the valley of the Stock Gill is reached. This may be entirely due to the accumulations of morainic material on the summit; but it seems probable that the Kirkstone Pass had once the same form, and was originally due to the same cause, as the Dunmail Raise, and that the cutting back of the Stock Gill has been the cause not of the gap itself, but only of a modification in its form. If this be so, the Kirkstone Pass marks the valley of an old river, which formerly flowed from the north through Ullswater to the

These two masses of high ground are separated by the gap of the Dunmail Raise; but this gap is in no way, or at most to a very slight degree, due to lessened elevation, the whole, or nearly the whole, of the depression being due to an excess of erosion. We may consequently leave it out of consideration in determining the original form of the elevated mass, or more properly that which it would have assumed had there been no denudation. Considered in this way, we find that it is not a dome, but a barrel-vault, terminating in the west in a semidome; to the east the axis continues beyond the area of the Lake District, and its further continuation need not be considered.

The recognition of an axis, as opposed to a centre, of elevation, does away with the necessity of attributing the elevation to the intrusion of a laccolite, but does not preclude the possibility of this cause, for there is no necessity for the symmetry of a laccolite to be radial and give rise to a dome-shaped elevation, though such is doubtless the most common form. A weightier objection is to be found in the history of the Dunmail Valley; the elevation of the hills evidently took place slowly, for a period sufficient to allow the river to lower its bed at least 2000 feet before elevation was able to master erosion. So slow and prolonged an elevation appears to be incompatible with its being caused by the intrusion of a laccolite, a cause which is likely to produce a comparatively rapid elevation of the surface.

Another point in which the explanation of the Dunmail Raise here offered comes into contact with previously proposed explanations of the origin of the surface-features of the Lake District, is

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Windermere Valley, a river which was interrupted and divided at an earlier period than that of the Dunmail Raise.

The Stake Pass may similarly mark the course of a river which crossed this area from the north, flowing along what is now the Borrowdale valley; but of this I cannot speak, as I have not seen the pass.

that which concerns the origin of the drainage-system. This is generally regarded as having been marked out, in its main features, at the time of the original uplift on the surface of the Carboniferous, and possibly newer, rocks which are believed to have extended across the region now occupied by the mountains of the Lake District. In other words, the principal valleys are regarded as originally consequent on this uplift, their direction being determined by the slope given to the original plain, whether of deposition or marine denudation, and as being superimposed on the rocks out of which they are now carved. This last hypothesis is unaffected by the explanation of the Dunmail Raise here offered, but the first is seriously affected. If my explanation is correct, it follows that a well-established river crossed the uplift at the time of its commencement, and this river was sufficiently powerful to cut down its channel as the uplift proceeded, continuing for a long time as an antecedent river. This practically necessitates the conclusion that the surface, affected and modified by this elevation, was not a plain of marine deposition or denudation, but a peneplain of subaerial denudation,[1] and it is possible that the principal northern drainage-lines other than the Thirlmere Valley were determined by reversals of the original drainage of the peneplain, due to the changes of level and slope caused by the elevation, in which case the valleys are reversed; but it is more probable that the present drainage-system was largely determined by a modification of the old one through cutting back by erosion into the rising mass of high ground,[2] in which case the principal lines of drainage must be regarded as subsequent.

This is, however, subsidiary to the main object of this communication, the explanation of the Dunmail Raise. The questions of what was the original extent of the drainage-area of the Dunmail River, and of what was the origin of the other drainage-lines in the Lake District, demand a more detailed and extended study than I have been, or am likely to be, able to devote to them. They will in any case be difficult to answer, and in view of the great changes in the details of surface-forms wrought during the Ice Age, it may be doubted whether they will ever be capable of certain solution.

Discussion.

Dr. H. R. Mill said that he believed the radiate symmetry of the valleys of the Lake District was first referred to by the poet Wordsworth, who considered only the western half of the district with Sca Fell as a centre. He himself had used the idea of radiate symmetry as a convenient way of fixing the somewhat difficult configuration of the district in the mind of a reader unacquainted with the region; and while naturally interested and pleased when

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[1] This conclusion will of course be strengthened, if the suggestion regarding the origin of the Kirkstone Pass (footnote [1], p. 193) is accepted.

[2] With the possible exceptions of the Borrowdale and Ullswater valleys, see footnote, p. 194.

Mr. Marr brought forward geological evidence of a dome-like structure having actually existed, he did not himself presume to express an opinion on the matter. He thought that the Author's theory might explain several features in the configuration, such as the inward trend of the Glenderamackin Valley, and the double basins which appear more or less distinctly in Derwentwater and Bassenthwaite Lake, which did not fit into the theory of dome-structure.

Mr. A. E. Salter asked whether the solid strata below confirmed the Author's theory of upheaval, and whether any fluviatile deposits of the old river postulated in the paper had been found. He was glad to note that the Author, with his wide experience, favoured the work of subaerial agencies rather than marine in explaining the phenomena observed.

Mr. J. E. Clark asked whether the Author had sufficiently considered the tremendous rainfall of the Lake District. The streams when quiescent give no idea of the tremendous volume hurrying down the valleys in storms: it has been said that the Derwent at Cockermouth carries more water to the sea than any other river in England. The Author's references to the morainic deposits near Dunmail Raise were hardly conclusive proofs that they were records of the intensest epoch of the Glacial Period. That was a time when almost all the area was ice-submerged, implying far more powerful effects.

Mr. A. Strahan reminded the Author that 'through valleys,' such as he had described, occurred in many mountain-regions. One traversing North Wales had been recently described by Mr. Lake, by whom a somewhat similar theory had been put forward. The Isle of Man was almost cut in two by such a valley, and others occurred in Scotland and elsewhere. The contoured map exhibited scarcely seemed to support the Author's contention that the region had been traversed from north to south by a main river. It showed that the water-parting of the Lake District, though of no great length, ran generally east and west, and that the high land composing it exhibited no such bisection as would have been produced by the passage of a main river. It presented various stages in the process of breaking down, and the case described by the Author was merely the furthest advanced of several examples. At that point the Wyth Burn, flowing northward, was overlapped by the headwater of the Raise Beck flowing southward. Between them the two streams left a narrow tract, in which a gap appeared to have originated by the crumbling away of the rocks along a line of weakness, possibly due to the outcrop of a soft bed or to a fault. The solid geology, however, seemed to have been left out of account. While not accepting the Author's conclusions, he thought the paper highly suggestive.

Mr. W. Whitaker, the Rev. J. F. Blake, and Mr. G. W. Lamplugh also spoke.

The Author, in reply, said that the photographs exhibited by him were taken by Messrs. Walmsley Brothers and Mr. H. Bell of

Ambleside. He had experienced personally the possibilities of rainfall in the Lake District, and had made allowance for it in his statement that the existing streams on the Dunmail Raise were misfits. An observer of any experience should have no difficulty in making allowance for variations in volume of streams, as the flood-marks were certain signs of the maximum volume attained by the stream. With regard to the solid geology he had said nothing, as that had been fully treated by other authors. He had contemplated the possibility of the depression of the Dunmail Raise being due to a band of softer rock, but could find no support for the supposition, either in the solid geology or in the form of the Dunmail Raise itself. The form of a valley depended on the rock in which it was carved; but this did not affect the progressive widening of the presumed Dunmail Valley from north to south, or the direction of the tributary valleys. In speaking of the extraordinary character of the gap, he had looked to the rarity of recorded cases of reversal of drainage by upheaval, to the recognition of the old valley across the barrier, and to the depth to which the old river had cut its valley through the rising mountain-mass before its course was finally interrupted.